APPARATUS FOR CONDITIONING WELL BORES

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The present invention relates to apparatus for performing various operations in well bores, such as drilling, milling, hole enlarging and cementing.

An object of the invention is to provide apparatus capable of performing a cutting operation in a well bore, to provide an open region therewithin, jetting of fluid under high velocity against the wall of the well bore, and circulating fluid through the lower end of the apparatus so that it is capable of washing away bridges, and the like, that might develop as the result of the jetting action of the fluid.

Another object of the invention is to provide apparatus capable of performing a cutting operation in a well bore, to provide an open region therein, the apparatus having a relatively large passage area through which fluid can be pumped during the cutting operation, this passage area being considerably reduced to produce a jetting action of fluid at a comparatively high velocity against the wall of the open bore, while still permitting the circulating fluid to discharge through the lower end of the apparatus for the purpose of removing sand bridges and similar obstructions that might be present in the well bore below the apparatus.

A further object of the invention is to provide an apparatus having a relatively large passage area through which fluid can be pumped in an open well bore, this passage area being considerably reduced to produce a jetting action of fluid at a comparatively high velocity against the wall of the well bore, but still permitting circulating fluid to discharge through the lower end of the apparatus for the purpose of removing sand bridges and similar obstructions that might be present in the well bore below the apparatus during the time that the jetting action is occurring.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of several forms in which it may be embodied. Such forms are shown in the drawings accompanying and forming part of the present specification. These forms will now be described in detail for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

FIGURE 1 is a side elevation of an apparatus disposed in a well bore, a portion being shown in section;

FIG. 2 is an enlarged longitudinal section taken along the line 2—2 on FIG. 1;

FIG. 3 is an enlarged fragmentary cross-section taken along the line 3—3 on FIG. 2;

FIG. 4 is a bottom plan view of the apparatus disclosed in FIG. 1, on an enlarged scale;

FIG. 5 is a longitudinal section through a modified portion of the apparatus illustrated in FIG. 1;

FIG. 6 is a longitudinal section of the lower portion of still another form of the invention;

FIG. 7 is a combined side elevational view and longitudinal section through yet another embodiment of the invention disposed in a well bore;

FIG. 8 is an enlarged cross-section taken along the line 8—8 on FIG. 7.

As disclosed in the drawings, an apparatus A is illustrated which is capable of performing a cutting operation in a well bore B while circulating amenable fluid through a string of drill pipe C, or similar tubular string, connected to the apparatus, for the purpose of removing cuttings, and the like, from the tool. After the desired cutting operation has been performed in the well bore, the passage area through the apparatus is materially restricted so that fluid under high velocity can be jetted out through generally radial or lateral nozzles in the apparatus, acting against the wall of the well bore for the purpose of cleaning it of drilling mud, and the like, or of enlarging its diameter, and also for the purpose of depositing cementitious material in the well bore to form a plug therein.

During the time that the jetting action is occurring, it is desired to still be capable of discharging fluid in a generally longitudinal direction from the lower portion of the apparatus to enable the well bore to be cleared of any obstacles that might exist or be produced by the apparatus, so that the apparatus can be moved both downwardly and upwardly in the well bore during the jetting action. Despite the restriction in the flow from the apparatus, so that high velocity jets are present for action against the wall of the well bore, the tool can be cleared of cementitious material and other substances whenever desired by pumping fluid through the apparatus, capable of passing through a comparatively large area, insuring that a large volume of fluid is available for the purpose of appropriately cleaning or otherwise conditioning the apparatus.

In the form of invention illustrated in FIGS. 1 to 4, inclusive, the apparatus A is disclosed as constituting a milling tool, which may be of any desired type, as, for example, a milling tool illustrated in United States Patent No. 2,853,994. This tool is rotated by attaching the upper threaded box 10 of its body 11 to the lower pin end 13 of the string of drill pipe C, or corresponding tubular string, extending to the top of the well bore.

The milling or cutting tool has circumferentially spaced cutting blades 13 extending generally radially or laterally of the body, which have lower cutter edges 14 adapted to engage a liner (not shown), or the like, for the purpose of milling away the liner upon rotation of the drill pipe and the apparatus and pumping of drilling fluid down through the drill pipe and through the apparatus, the drilling fluid passing upwardly around the apparatus A, carrying the cuttings upwardly with it and around the drill pipe C to the top of the well bore B.

As illustrated in FIG. 1, the milling tool has already milled away a desired length of liner (not shown) to expose the wall of the surrounding well bore B, in which the milling tool is illustrated as being located. The fluid pumped down through the drill string C and through the central passage 15 of the body 11 of the apparatus can discharge in a generally radial or lateral direction through one or a plurality of jetting nozzles 16 extending through the wall of the body of the tool below the cutting blades 13, the nozzles being suitably secured to the body, as by welding or brazing. The fluid can also pass through the central body passage 15 to its lower portion 17 where it will flow through a lower nozzle 18, inserted upwardly in the lower end of the tapered guide or nose portion 19 of the body, and through a non-circular passage 20 in the lower part of the nozzle, which is surrounded by an upwardly facing seat 21.

During the time that the apparatus A is being lowered in the well bore on the string of drill pipe C, the passage 20 through the lower nozzle 18 is open. Accordingly, fluid can enter the body passage 15 freely for upward movement into the drill pipe C. In the form of invention disclosed in FIGS. 1 to 4, inclusive, such fluid can
also pass through the jetting nozzles 16, which are of a comparatively restricted area, opening into the central passage 15 through the body. Similarly, after the apparatus has been lowered into engagement with the liner for the performance of the milling operation, it is rotated and an ample quantity of drilling fluid pumped down through the drill pipe C, flowing through the central passage 15 of the body and simultaneously through the jetting nozzles 16, a large portion of the fluid passing down through the lower nozzle 18. The circulating fluid will then pass upwardly around the body 11 of the tool and the cutters 13, carrying the cuttings upwardly through the well bore B to the top thereof. During the time that the milling action is occurring, the jetting nozzles 16 will be impinging some fluid against the wall of the liner below the cutter edges 14 of the cutting blades 13. However, such jetting action may have very little effect on the liner.

After the wall of the well bore has been exposed by milling away a certain length of the liner, the tool A is elevated in the well bore so that the jetting nozzles can impinge fluid against the wall of the open well bore, for the purpose of conditioning it. To insure that fluid will issue at a comparatively high velocity through the jetting nozzles 16, the passage through the lower nozzle 18 is restricted by lowering or pumping a valve element 23, in the form of a ball, down through the drill pipe C, which will come to rest upon the seat 21 in the lower nozzle 18. Due to the non-circular shape of the lower passage 29 in the nozzle, the ball will not close such passage, but will merely restrict its area, allowing some fluid to still pass down through the nozzle 18 and discharge in a downward direction into the well bore B. The restriction in the area through the lower nozzle 18 will cause an increase in the velocity of the fluid discharging substantially radially from the jetting nozzles 16, such fluid impinging upon the wall of the well bore B and cleaning it of drilling mud, and the like. If desired, the fluid can be used to enlarge the diameter of the well bore B. During the jetting action of the fluid from the radical nozzles 16 against the wall of the well bore, and the drill pipe C and the apparatus A are rotated so that the nozzles cover the full circumference of the well bore and the tool is moved longitudinally in the open well bore along a desired length. Thus, the tool can be raised in the well bore and fluid jetted through its nozzles 16, and it can also be lowered therewith, the tool being raised and lowered as often as is deemed necessary for the purpose of appropriately conditioning the well bore B.

The jetting action against the wall of the well bore might dislodge formation material, which will ordinarily occur in the event that the jetting action results in an enlargement in diameter of the well bore B. The fluid issuing from the jetting nozzles 16 will carry the formation cuttings upwardly around the apparatus A and the drill pipe C to the top of the well bore B. However, some of the formation material may drop downwardly into the well bore and form a bridge which would tend to restrict or prevent downward movement of the apparatus A in the well bore. In the event that lowering of the apparatus causes it to encounter a bridge, and despite the presence of the ball member 23 on the seat 21, a sufficient quantity of fluid will still by-pass around the ball or flow restricting member, and through the nozzle 18, acting upon the bridge material for the purpose of washing it away and circulating it upwardly around the apparatus and the string of drill pipe to the top of the body.

After the open well bore B has been properly conditioned, it may be desired to deposit a cementitious plug (not shown) therewith. This can be done without removing the apparatus from the well bore. The required quantity of cementitious material is pumped down through the drill pipe C, and the major portion of it will issue through the jetting nozzles 15 and impinge against the wall of the well bore B. During the time that the cementitious material is issuing from the jetting nozzles into the open well bore, and starting from the region in the well bore at which the plug is to be formed, the drill pipe C and the apparatus A are rotated at the proper speed and the apparatus is gradually elevated in the well bore so that the cementitious material will strike the wall of the well bore and then shift downwardly to form a solid cementitious plug across the entire inner area of the hole B. Soon of the cementitious material, such as cement slurry, will also pass around the ball member 23 and discharge downwardly in the well bore. The apparatus is elevated in the well bore gradually while being rotated, until the required amount of cement slurry, or the like, has been deposited in the well bore, after which the apparatus can be elevated a sufficient distance above the cement slurry to allow cleaning fluid to be pumped down through the string of drill pipe and through the jetting nozzles 15 and the lower nozzle 18 and wash the excess cement slurry out of the apparatus and upwardly out of the hole. If desired, the cleaning fluid can be reversed circulated, being pumped downwardly into the annulus 25 between the drill pipe C and the wall of the well bore B, the cleaning fluid flowing inwardly through the jet nozzles 16 into the central passage 15 of the body, and also flowing outwardly through the lower nozzle 18, carrying the ball 23 upwardly with it. Any cementitious material in the tool and the ball or plug member 23, followed by the circulating fluid, will then pass upwardly through the drill pipe C for discharge at the top of the well bore. Such reverse circulation of fluid can occur through using a large volume of fluid and at a rapid rate, inasmuch as the upward removal of the ball 23 from the seat 21 presents a much larger passage area for the flow of the cleaning fluid than is present when circulating fluid is pumped downwardly through the drill pipe C for discharge in an outward direction through the radial jetting nozzles 16 and around the ball and through the lower nozzle 16.

Following the cleaning of the apparatus A, it can be removed from the well bore by elevating the string of drill pipe C therewithin, in a known manner.

The form of invention illustrated in FIG. 5 embodies a different fluid passage and nozzle structure at the lower end of the apparatus than disclosed in FIG. 1. It accomplishes the same purposes as the lower nozzle 18 and ball 23 in the apparatus illustrated in FIG. 1. In the apparatus shown in FIG. 5, the lower portion of the central passage 15 through the body of the tool B is closed and the jetting nozzle 16 has a plurality of downwardly diverging branches 30 opening to the exterior of the body. In each of these branches, a nozzle 31, 32 is secured in any suitable manner, as by welding or brazing, each of these nozzles having an upper valve seat 33. During the action of cutting or milling away the liner, or other object in the well bore, fluid is pumped down through the drill string C and through the body passage 15, discharging radially through the jetting nozzles 16 and also through the nozzles 31, 32 into the well bore, the fluid carrying the cuttings radially around the apparatus A and the drill pipe C to the top of the hole B. During this time, a large passage area is available through which fluid can flow between the central passage 15 of the tool body B and the surrounding well bore, such passage area being the combined areas of the jetting nozzles 16 and of the lower nozzles 31, 32.

When fluid at a high velocity is to be discharged through the jetting nozzles 16, the area through which fluid can discharge from the lower portion of the tool is decreased. As specifically shown, a ball member 23, or the like, is lowered or pumped down through the drill pipe and will pass through the central passage 15 and come to rest against one or the other of the nozzle seats 33, closing the passage through such nozzle completely,
As the result, jetting fluid can then only pass through the radial jetting nozzles 16 and through one of the lower nozzles 32. Thus, the velocity at which fluid now discharges through the jetting nozzles 16 has been increased, the jetting action occurring during the time that the drill pipe C and apparatus A are being rotated, and during the time that the apparatus is moved longitudinally in the well bore. Fluid is also discharged in a substantially longitudinal direction from the nozzle 32 that is not engaged by the valve ball 23, so that the fluid issuing therefrom in a downward direction can act upon any sand bridges, or the like, that might be produced by the jetting action of the fluid issuing from the upper nozzles 16 against the wall of the open formation thereby inuring that the apparatus can be moved in an upward and downward direction along the desired length of the well bore in conditioning the well bore, increasing its diameter, or in depositing a cementitious plug in the well bore by discharging the cementitious material through the jetting nozzles 16 and also through the lower nozzles 32 having the open passages.

After a cementing operation has been performed, the tool can also be elevated in the well bore above the discharged cement, and can be cleaned of cementitious material and other substances, either by pumping the long way through the drill pipe C and out through the jetting nozzles 16 and the lower nozzle 32 that has an open passage, or fluid can be pumped down through the annulus 25 around the drill pipe C passing inwardly through the jetting nozzles 16 and upwardly through both of the lower nozzles 32, 52, carrying the ball 23 upwardly through the central body passage 15 and through the drill pipe C to the top of the well bore.

In the form of invention disclosed in FIG. 6, the lower nozzle 18 illustrated in FIG. 1 has been replaced by a central nozzle 49 in the lower end of the body passage 15, which is suitably secured to the body, and by a bushing 70 that connects the drill pipe C and the lower body passage 15 of the upper radial jetting nozzles 16 and the areas of the lower nozzles 40, 41. After a milling or other cutting operation has been completed in the well bore, and it is desired to have fluid jet from the radial nozzles 16 at a high velocity, the area through which fluid can discharge from the lower portion of the apparatus is decreased substantially, as by lowering or pumping the ball 23 down through the drill pipe and through the body passage 15 into engagement with the circular valve seat 43 in the lowermost nozzle 40, fully closing the passage of the latter. Fluid or cementitious material pumped down through the apparatus will now pass at a high velocity through the radial jetting nozzles 16, and such fluid will also pass in a predominantly downward direction through the inclined nozzle 41.

The apparatus disclosed in FIG. 6 operates in the same manner as the apparatus illustrated in FIG. 1. In the event that a bridge, or the like, forms in the well bore below the apparatus, circulating fluid issuing through the branching nozzle 41 will strike such sand bridge, the apparatus being rotated while fluid is being discharged therefrom so as to wash the sand bridge away completely, the apparatus then being moved through the well bore within being carried upwardly around the apparatus A and the drill pipe C to the top of the well bore.
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or enlarge its diameter, or the pumping of the cementitious material through the nozzles will cause such cementitious material to expand against the wall of the well bore and then shift downwardly into the well bore to form a bridge therewith. Some of the fluid is still by-passing around the ball valve element 23 and flowing downwardly through the drill bit 63 and its nozzles 65 to wash away any bridges, or the like, that might form in the well bore so as not to impede upward and downward movement of the apparatus in the well bore and its rotation while the jetting action is being performed.

As in the other forms of the apparatus, in the event it is used for pumping cementitious material into the well bore, it can be cleaned of such cementitious material by pumping fluid down through the drill pipe C and the apparatus A, the fluid passing through the jetting nozzles 67, and also around the ball valve member 23 and through the drill bit 63, to clear all regions of the apparatus of the cementitious material. Similarly, as in the other forms of the invention, circulating fluid can also be pumped down through the annulus 25 around the drill pipe C, passing inwardly through the radial jetting nozzles 67, and also in through the drill bit nozzles 65, flowing upwardly through the drill bit passage 64 and the body passage and sleeve 65, carrying the ball 23 upwardly or downwardly through the drill bit passage 64 and the drill pipe C to the top of the well bore, thereby leaving an unobstructed passage through the apparatus, which now may, if desired, be removed from the well bore.

In all forms of the apparatus, after the flow restricting valve member 23 has been pumped out of the well bore, elevation of the drill pipe C will result in fluid drainage therefrom into the well bore through all flow passage areas in the apparatus, so that the chance of pulling a "wet string" at the top of the hole is greatly reduced, if not completely eliminated.

1. In apparatus adapted to be lowered in a well bore on a tubular string: a fluid jetting device including a rotary drill bit having cutting means thereon for performing a cutting action in the well bore; said device having a fluid passage adapted to receive fluid from the tubular string and including a generally radial nozzle below said cutting means for directing fluid from the passage against the wall of the well bore; means in said device below said nozzle and communicating with said passage for discharging fluid from the lower portion of the device in a downward direction into the well bore; and rigid means engageable with said discharging means for partially closing said discharging means to restrict the flow of fluid therethrough.

2. In apparatus adapted to be lowered in a well bore on a tubular string: a fluid jetting device including a rotary drill bit having cutting means thereon for performing a cutting action in the well bore; said device having a fluid passage adapted to receive fluid from the tubular string and including a generally radial nozzle below said cutting means for directing fluid from the lower portion of the device in a downward direction into the well bore; and rigid means engageable with said discharging means for partially closing said discharging means to restrict the flow of fluid therethrough.

3. In apparatus adapted to be lowered in a well bore on a tubular string: a fluid jetting device including a rotary drill bit having cutting means thereon for performing a cutting action in the well bore; said device having a fluid passage adapted to receive fluid from the tubular string and including a generally radial nozzle below said cutting means for directing fluid from the lower portion of the device in a downward direction into the well bore; and rigid means engageable with said discharging means for partially closing said discharging means to restrict the flow of fluid therethrough.
9. In apparatus adapted to be disposed in a well bore in a tubular string: a rotary drill bit having cutting means thereon for performing a cutting action in the well bore and having a fluid passage adapted to receive fluid from the tubular string; a generally radial first nozzle in said bit communicating with said passage and disposed substantially normal to the bit axis for directing fluid against the wall of the well bore; an initially open second nozzle in the lower portion of said bit below said first nozzle and communicating with said passage for discharging fluid in a downward direction into the well bore, said second nozzle having a non-circular passage; and flow restricting means engageable with said second nozzle and disposed across said non-circular passage to partially close said non-circular passage and cause fluid to flow around said flow restricting means and through said passage into the well bore.

10. In apparatus adapted to be disposed in a well bore on a tubular string: a rotary drill bit having cutting means thereon for performing a cutting action in the well bore and having a fluid passage adapted to receive fluid from the tubular string; a generally radial first nozzle in said bit below said cutting means communicating with said passage and disposed substantially normal to the bit axis for directing fluid against the wall of the well bore; a plurality of nozzles in said drill bit below said first nozzle and communicating with said passage for discharging fluid in a downward direction into the well bore; and rigid means engageable with one of said plurality of nozzles for closing the same.

11. In apparatus adapted to be lowered in a well bore on a tubular string: a fluid jetting device including a rotary drill bit having cutting means thereon for performing a cutting action in the well bore; said device having a fluid passage adapted to receive fluid from the tubular string and including a generally radial nozzle below said cutting means for directing fluid from the passage against the wall of the well bore; means in said device below said nozzle and communicating with said passage for discharging fluid from the lower portion of the device at its lower terminus in a downward direction into the well bore; and rigid means engageable with said discharging means for partially closing said discharging means to restrict the flow of fluid therethrough.

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